



# *ISTEP*

integrated Study and Test for Earthquake Precursors

## Seismo-ionospheric Precursors Probed by Global Navigation Satellite System during the 12 May 2008 M8.0 Wenchuan Earthquake

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National Central University, TAIWAN

International Beacon Satellite Symposium BSS-2016

Trieste, Italy



大學學術追求卓越發展計畫

地震電磁前兆研究

Program for Promoting University Academic Excellence - Research on Seismo-Electromagnetic Precursors of Earthquake

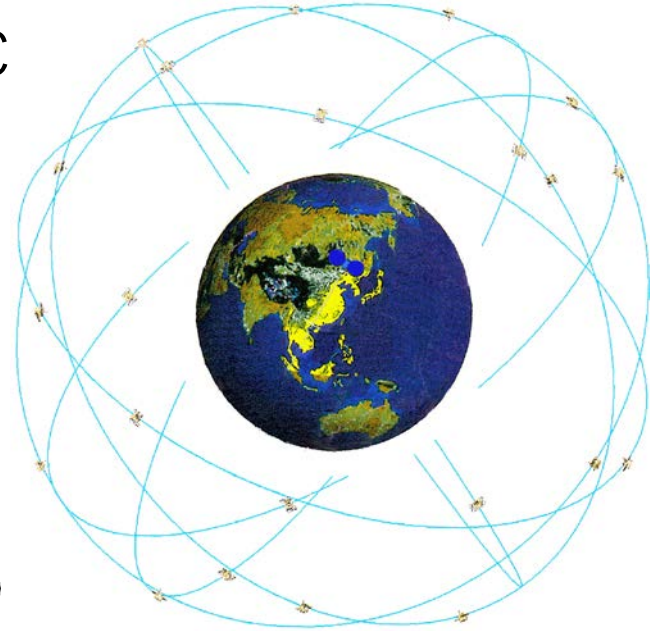
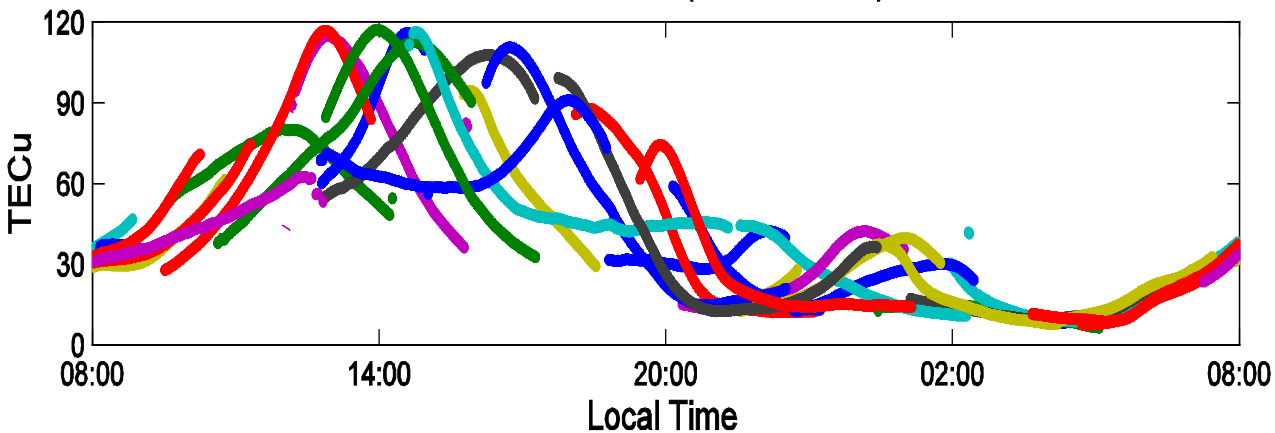
# Content

- GIM TEC detects seismo-ionospheric precursors (SIPs)
- Statistical analysis of SIPs associated with 36  $M \geq 6.0$  earthquakes
- Spatial SIPs in the GPS TEC of the M8.0 Wenchuan Earthquake
- Radio occultation observes SIP structures of the ionospheric electron density
- Conclusion



# Ionospheric total electron content (TEC) derived from GPS

Receiver: YMSM (North Taiwan)



TEC (total electron content)  
unit: TECu ( $10^{16}$  ele/m<sup>2</sup>)

ionosphere

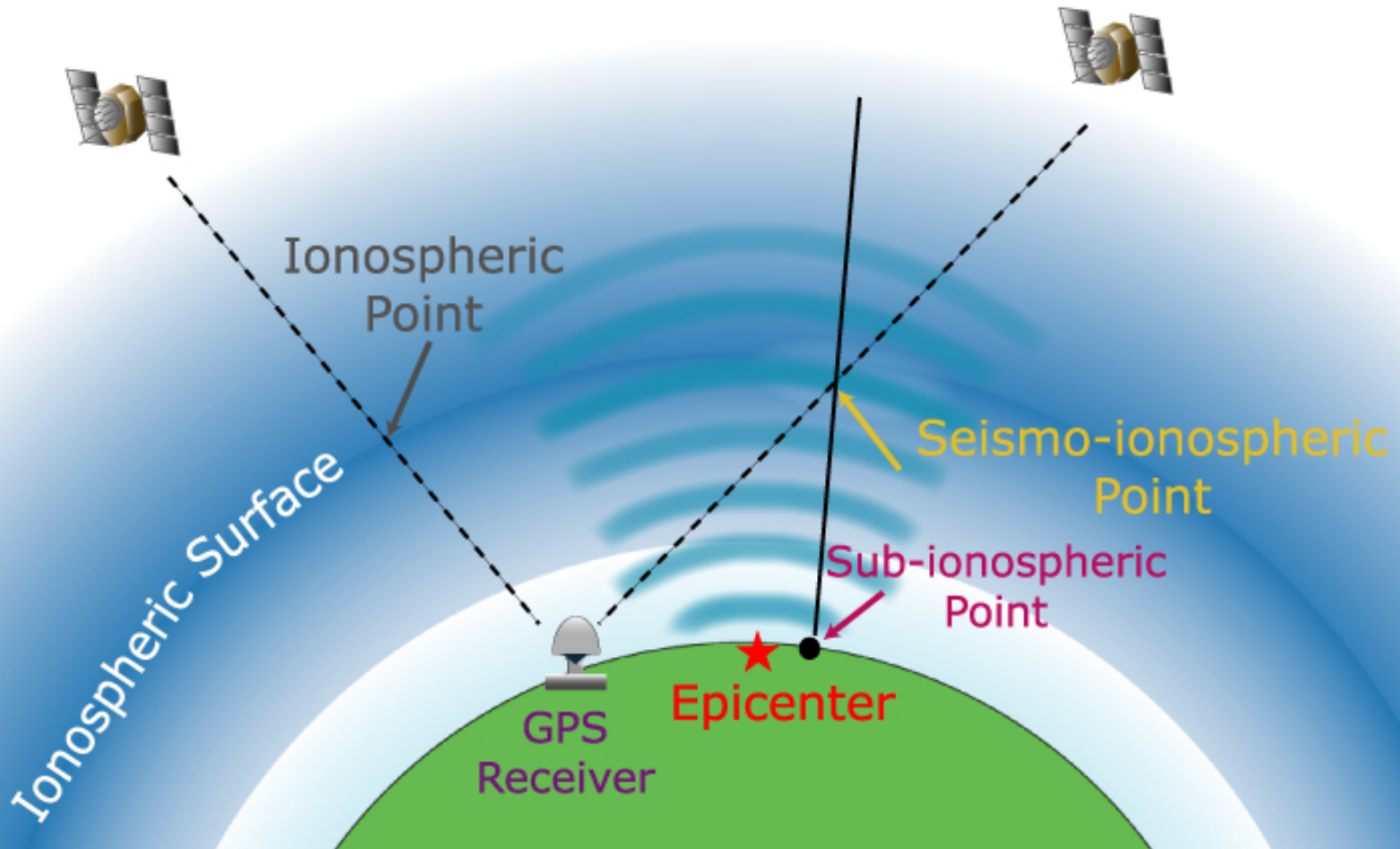
Line-of-sight

$$S_o = [(x^i - x_j)^2 + (y^i - y_j)^2 + (z^i - z_j)^2]^{1/2}$$



$(x_j, y_j, z_j)$

# SIP observed by GPS TEC



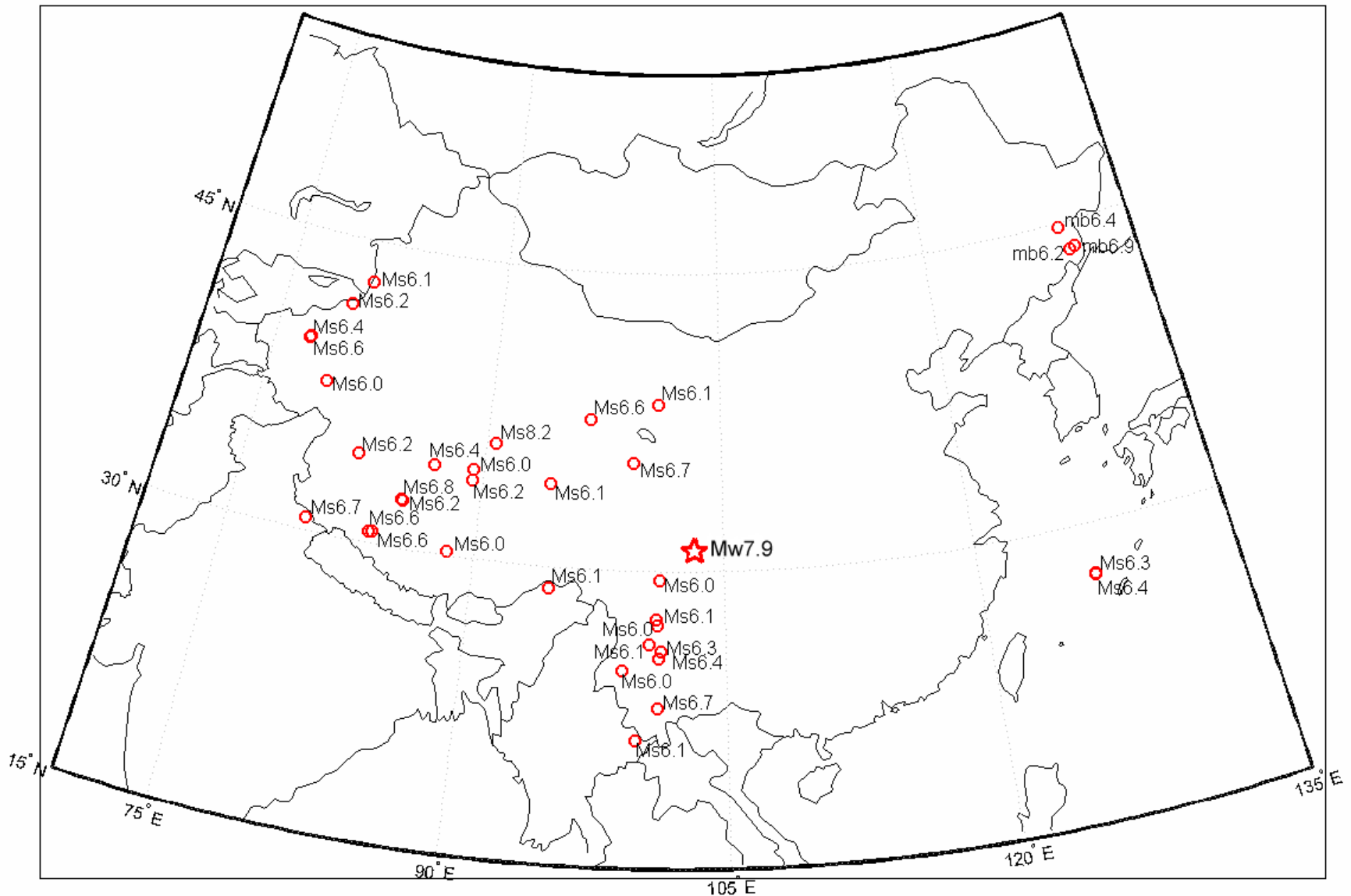
# China Earthquakes

1998/05/01~2008/05/12 36  $M \geq 6.0$  earthquakes

2008/5/12 M7.9 Wenchuan Earthquake

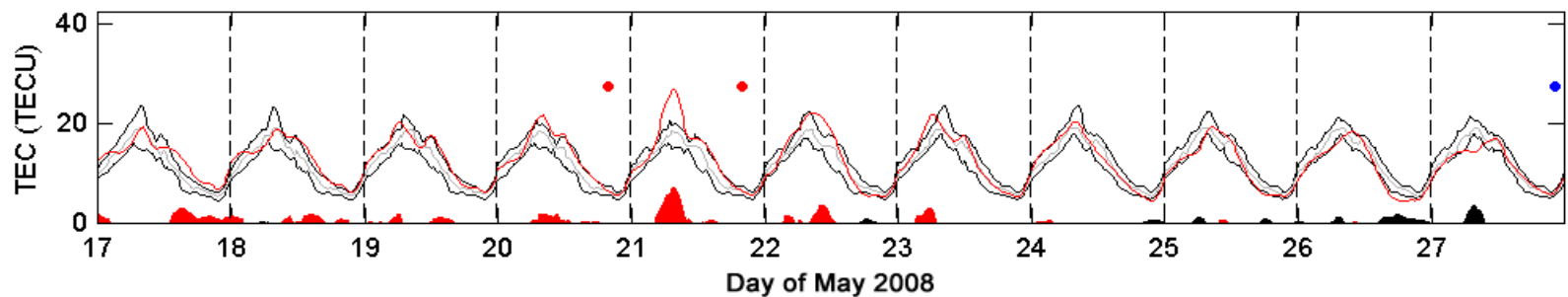
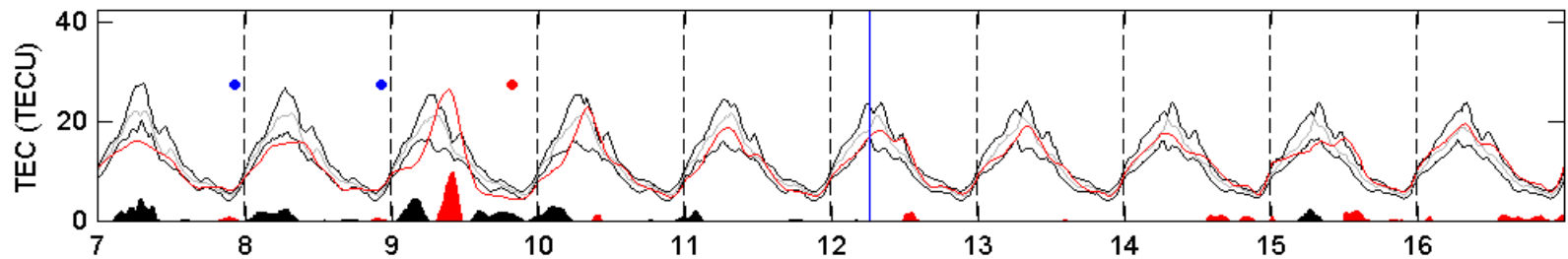
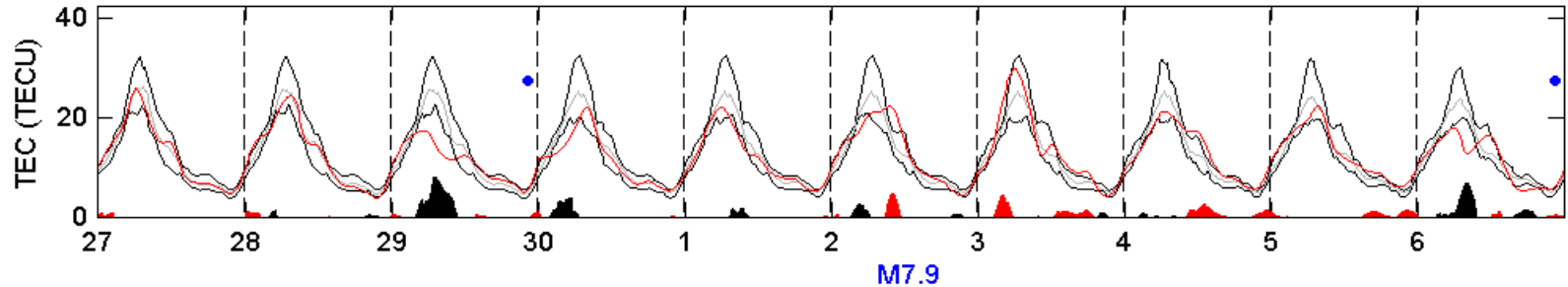
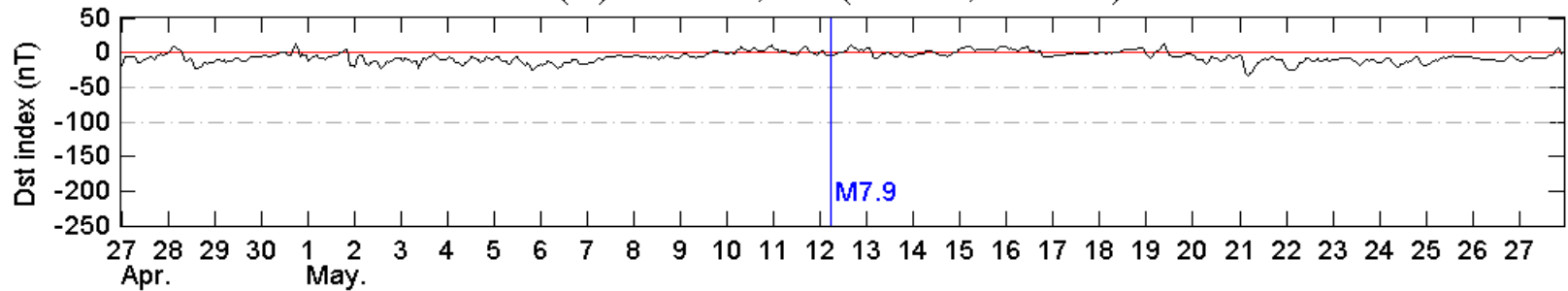


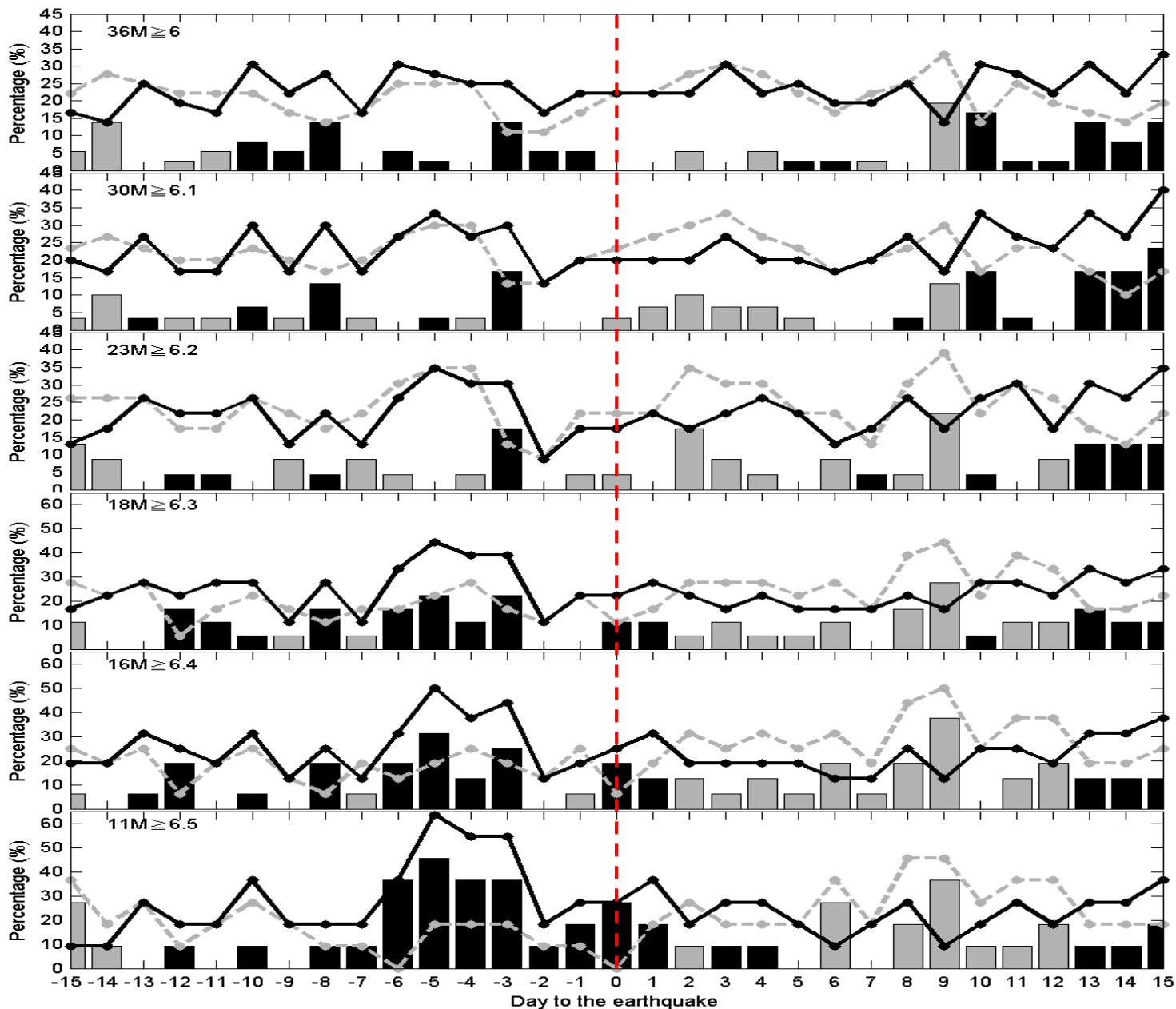
# Locations of the $35M \geq 6.0$ earthquakes together with the Wenchuan earthquake occurred in China during May 1, 1998-May 12, 2008.



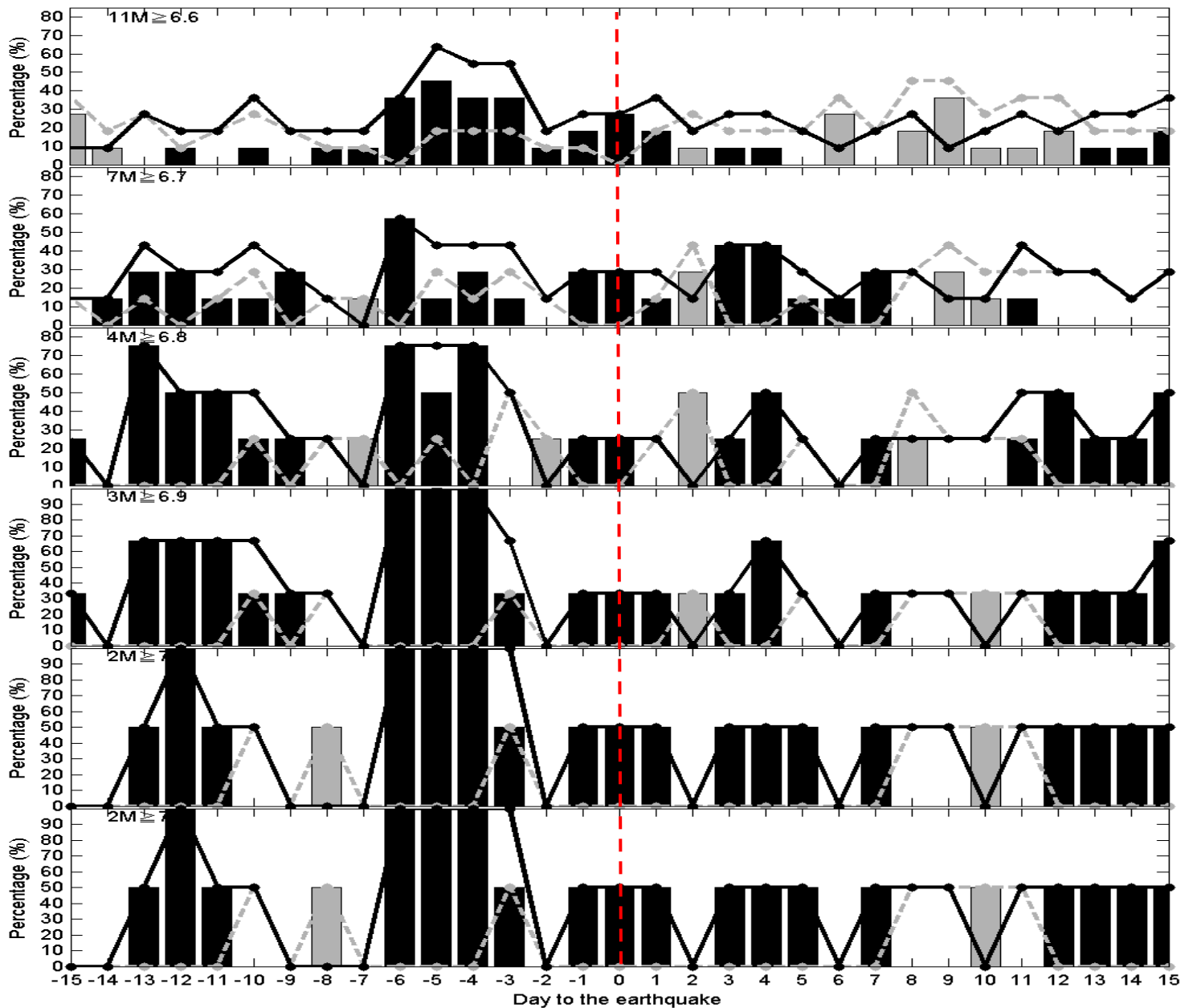
# A time series of GPS TEC right above the epicenter of the M8.0 Wenchuan earthquake on May 15, 2008.

(01) 2008/05/12, M7.9 (30.986°N, 103.364°E)





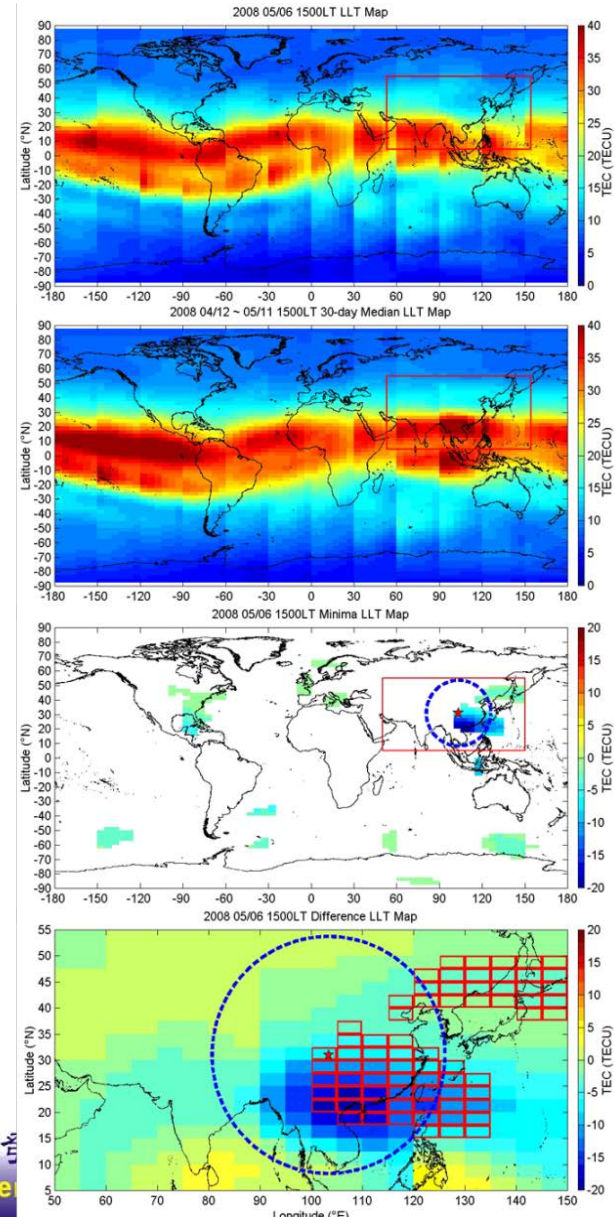
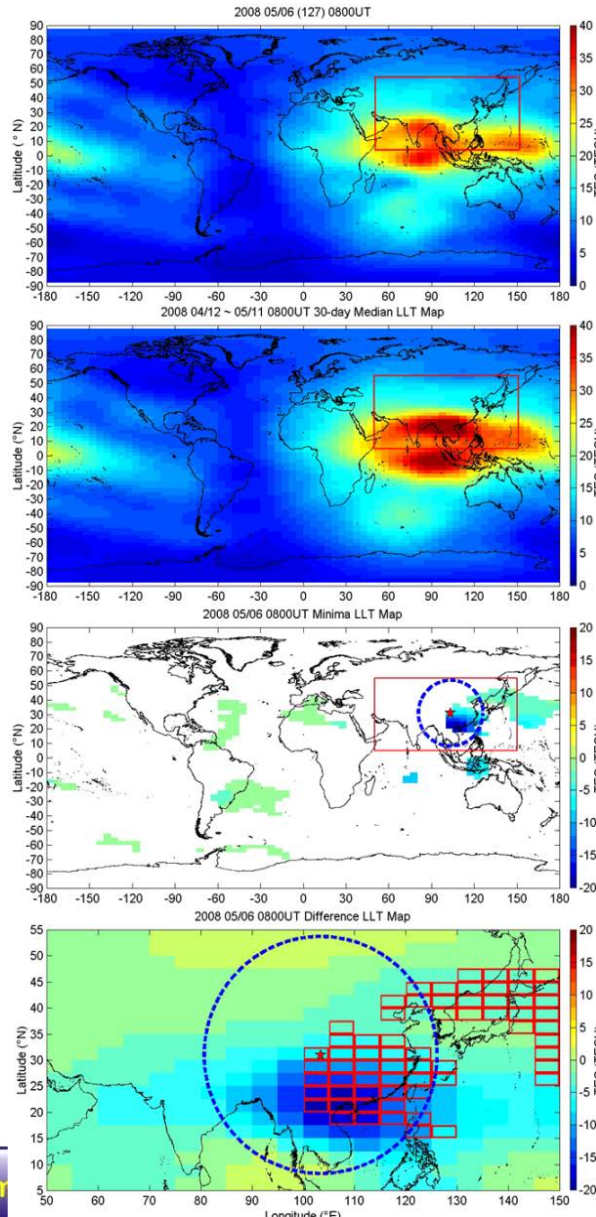




# The GIMs observed at 08:00UT and global fixed 15:00 LT on day 6 before the 2008 Mw7.9 Sichuan Earthquake.

0800UT

1500LT

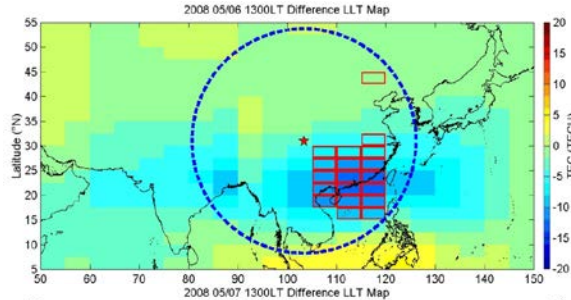
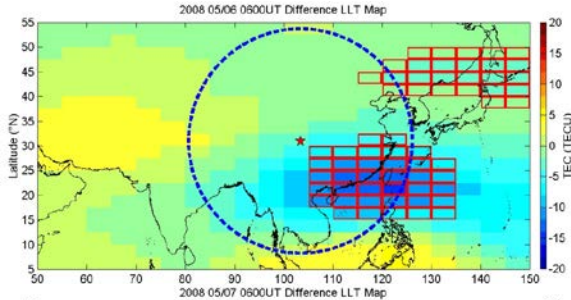


$$R = 10^{0.43M}$$

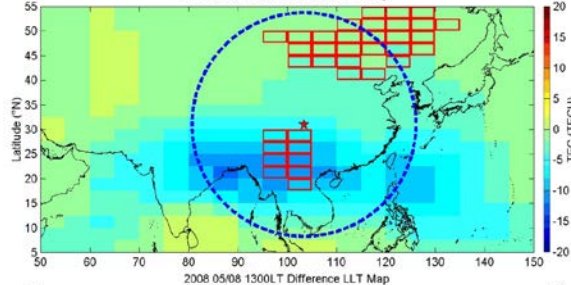
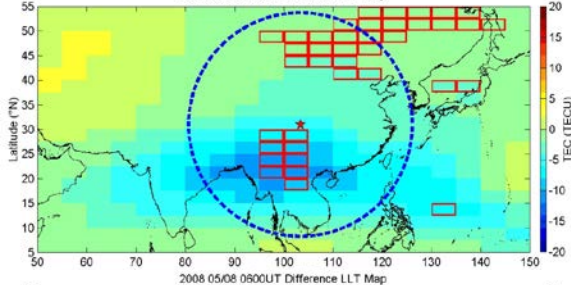


Program

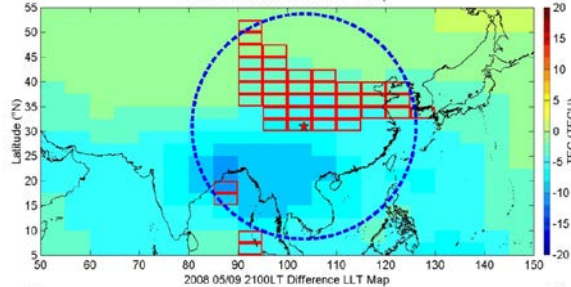
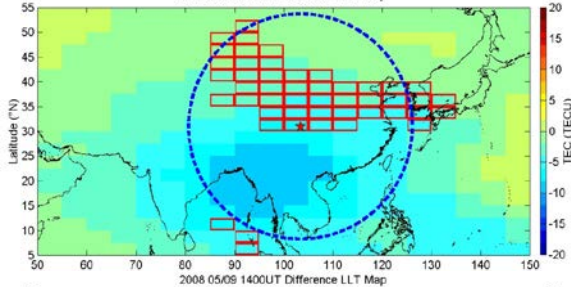
電磁前兆研究  
Precursors of Earthquake



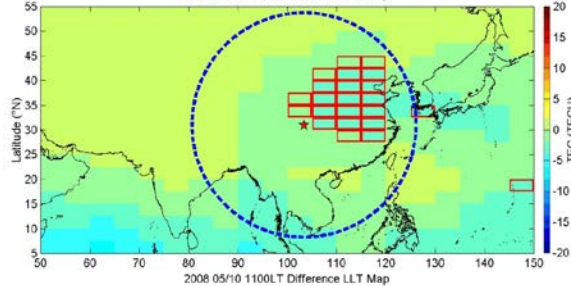
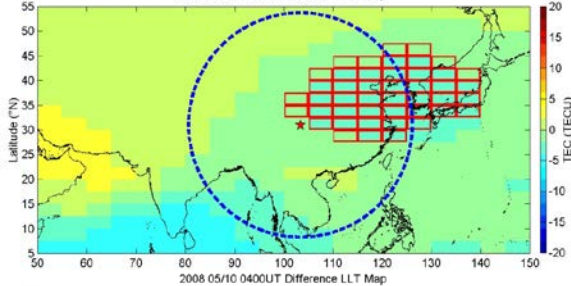
D-6, 5/6 2008  
0600UT, 1300LT



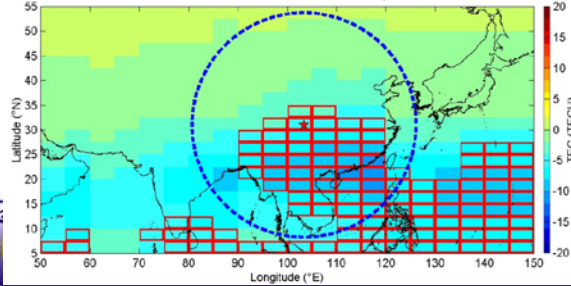
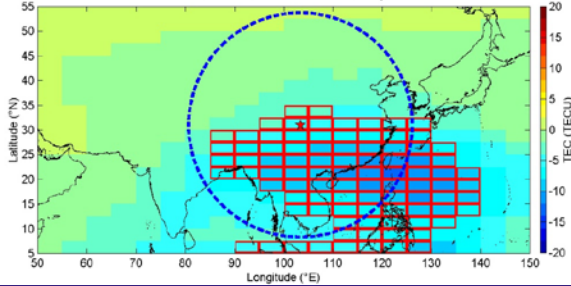
D-5, 5/7 2008  
0600UT, 1300LT



D-4, 5/8 2008  
0600UT, 1300LT



D-3, 5/9 2008  
1400UT, 2100LT

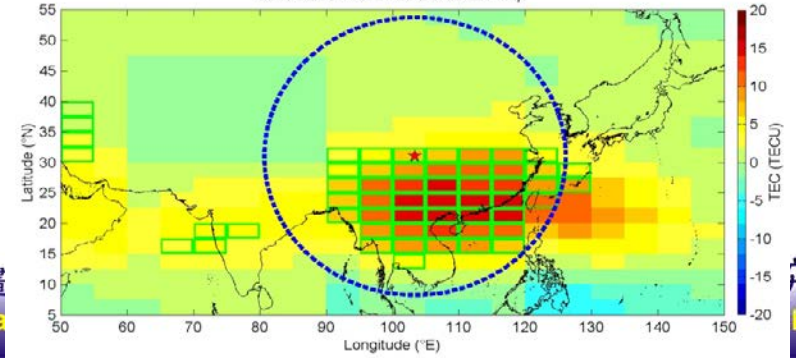
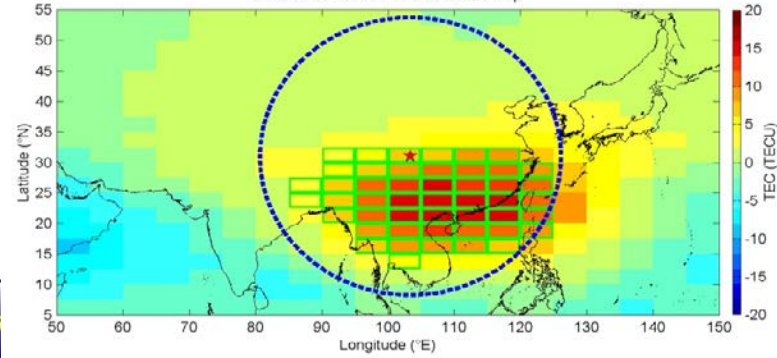
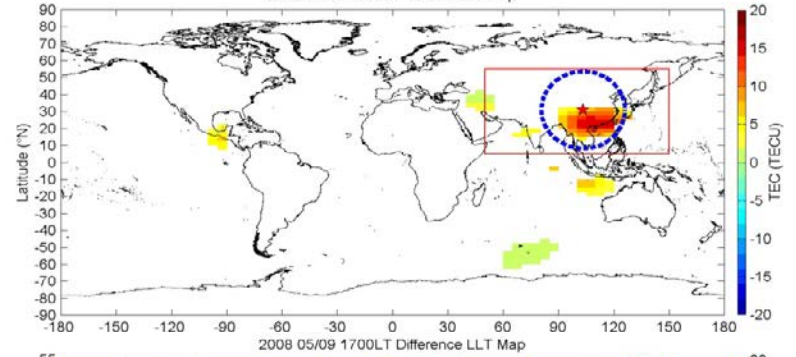
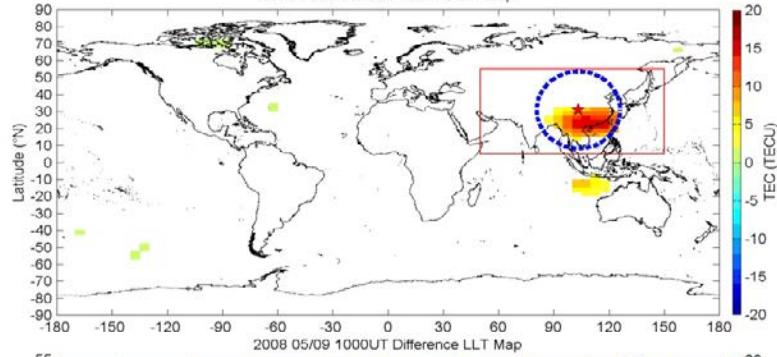
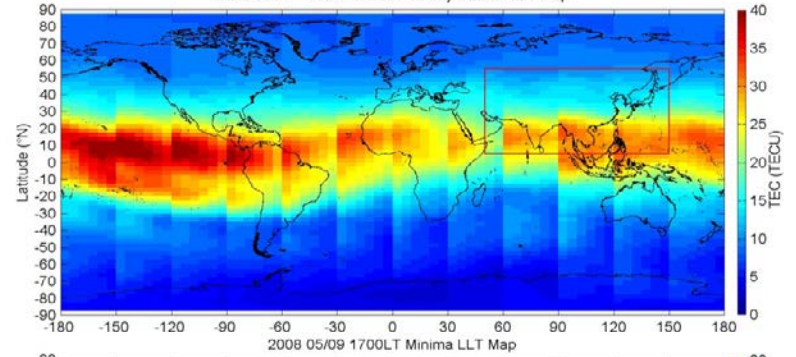
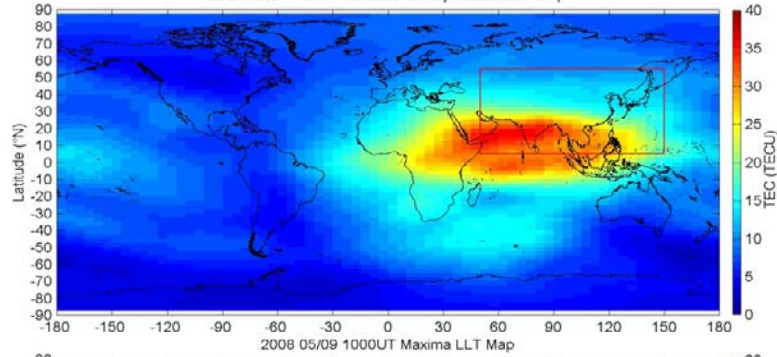
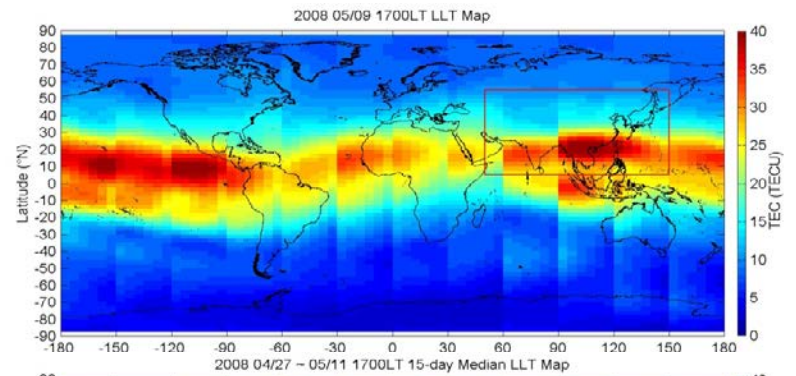
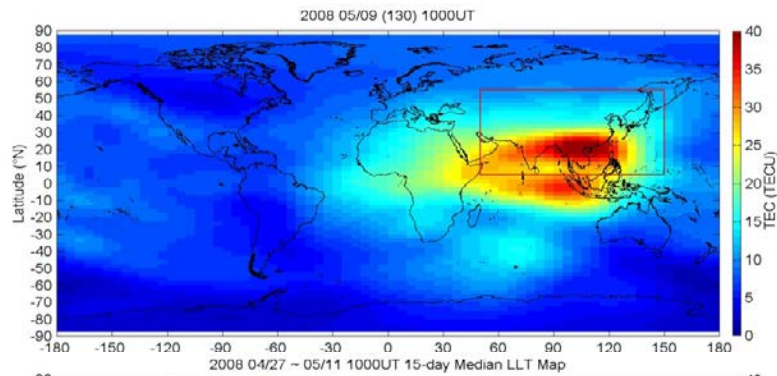


D-2, 5/10 2008  
0400UT, 1100LT

震電磁前兆研究  
Magnetic Precursors of Earthquake

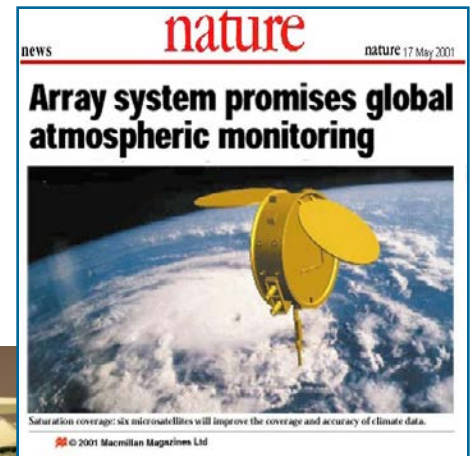


# D-3





## FORMOSAT-3/COSMIC

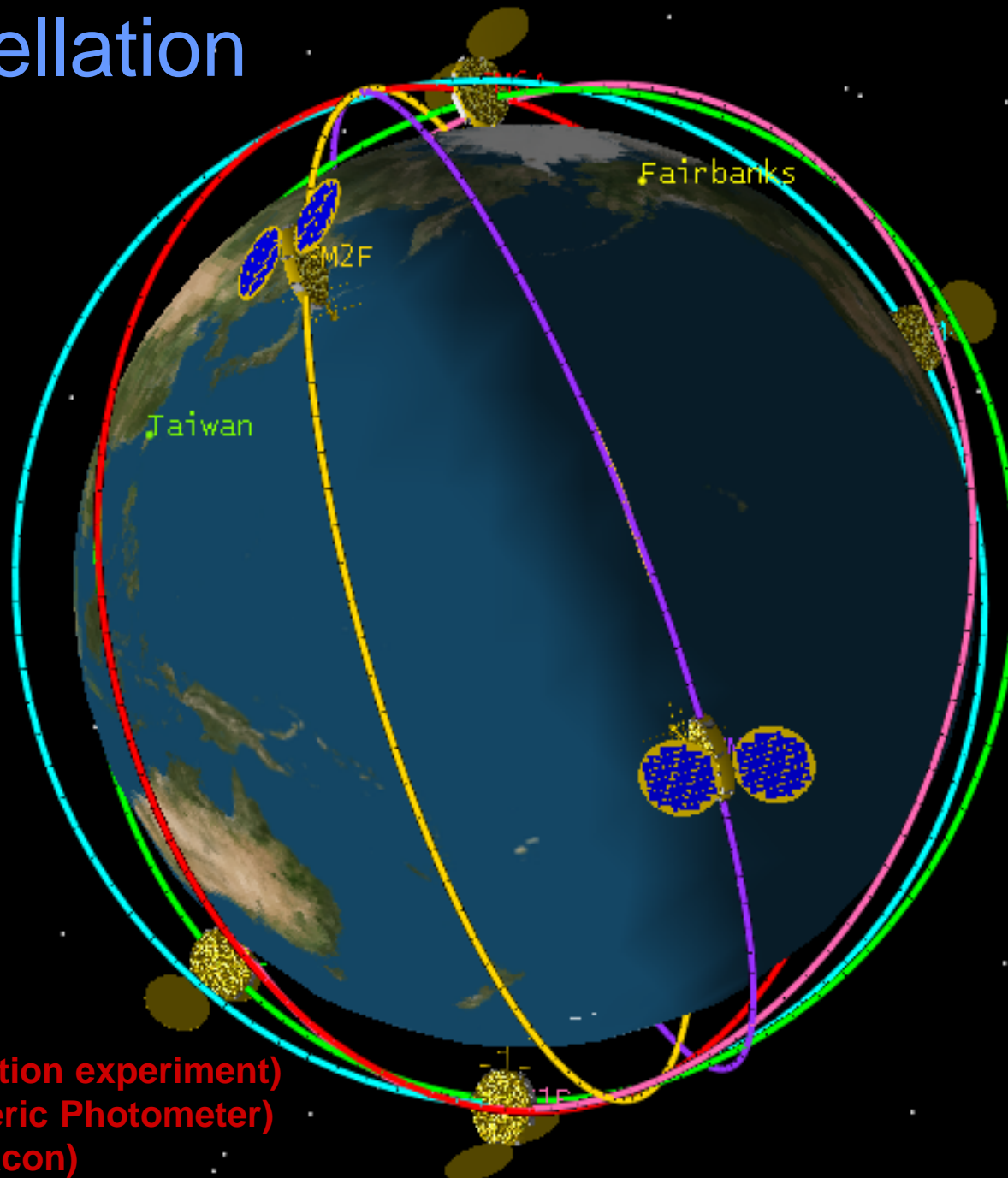


FORMOSAT-3/COSMIC Constellation was launch at 01:40 UTC, April 14, 2006 (Taiwan Time: April 15 2006) at Vandenberg Air Force Base, CA. Minotaur Launch. Initial orbit altitude ~515 km; inclination ~72° maneuvered into six different orbital planes for optimal global coverage (at ~800 km altitude)

COSMIC (Constellation Observing System for Meteorology, Ionosphere and Climate)

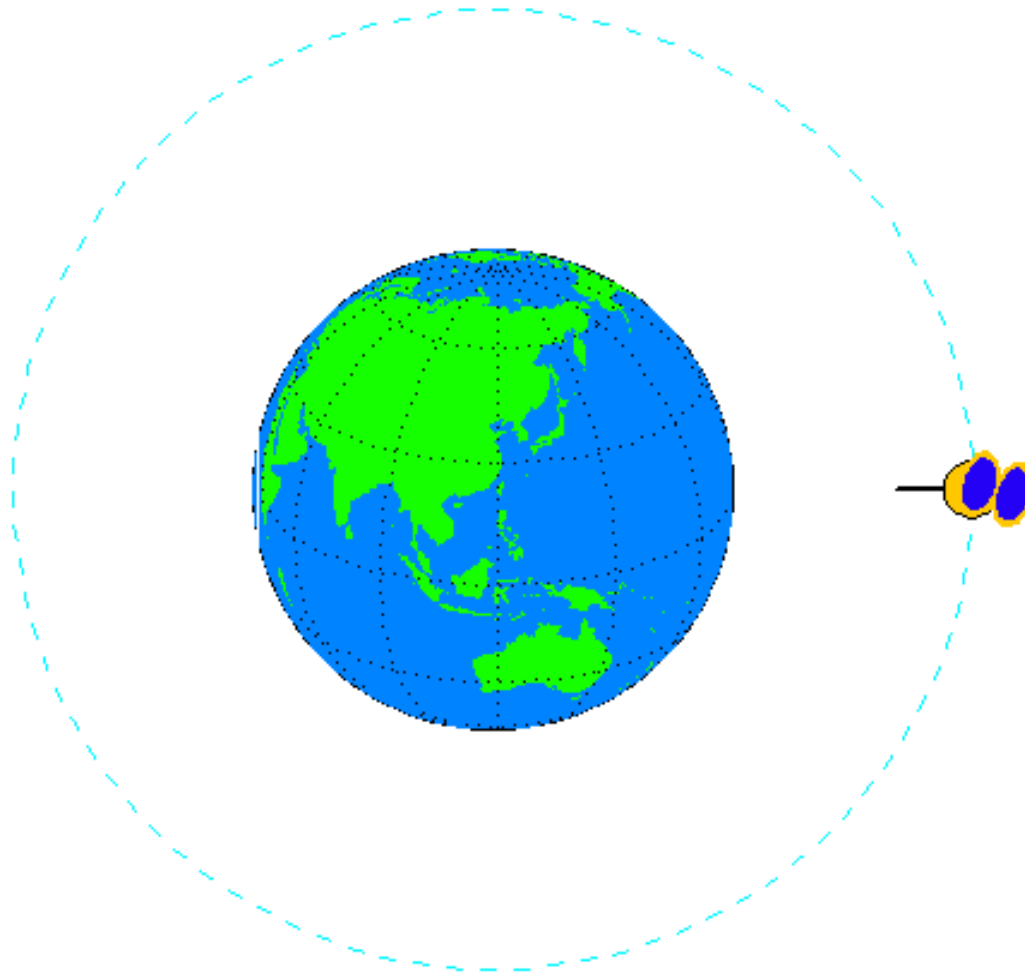


# Constellation



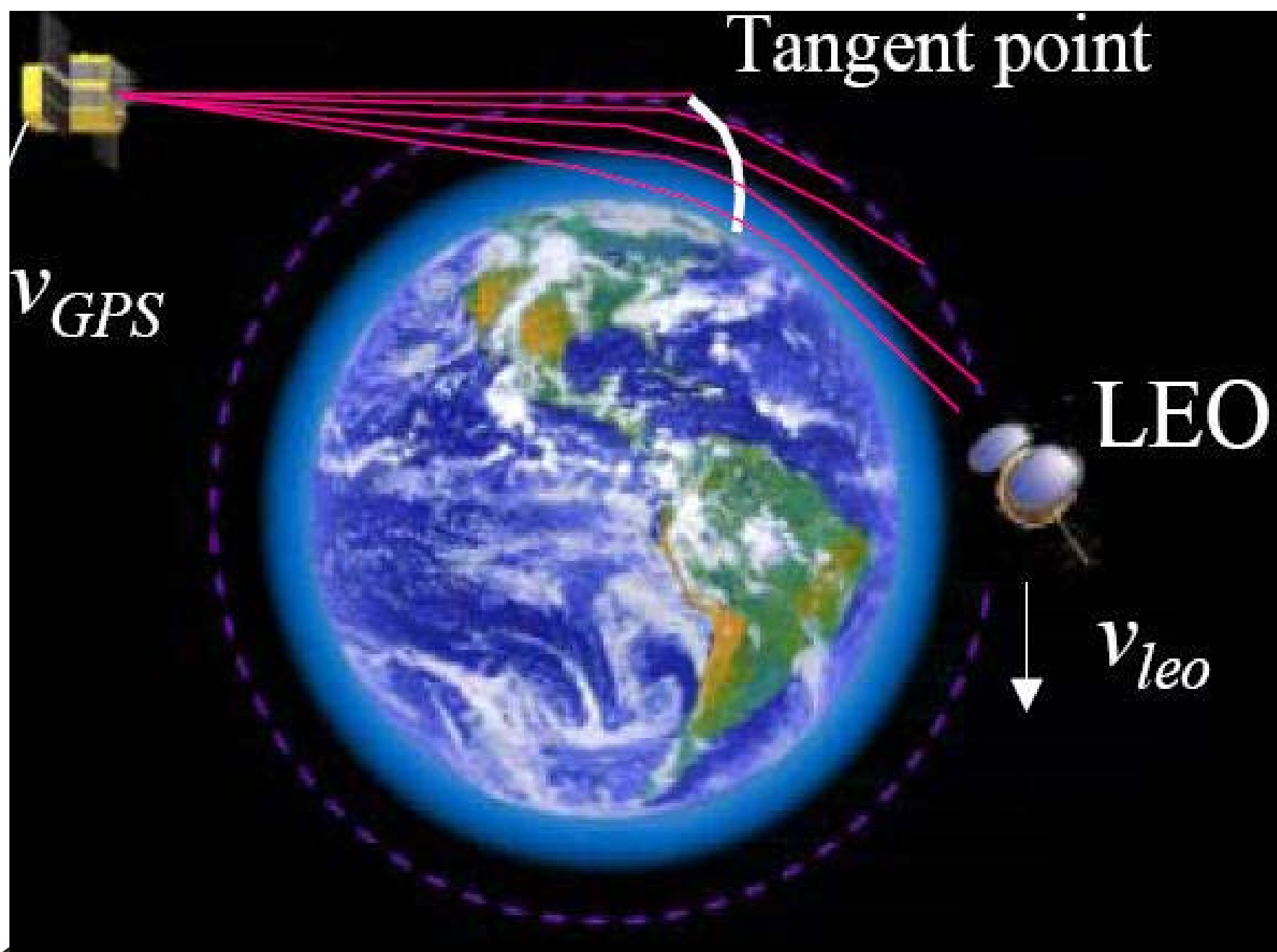
GOX (GPS occultation experiment)  
TIP (Tiny Ionospheric Photometer)  
TBB (Tri-Band Beacon)

# F3/C GPS Occultation Experiment



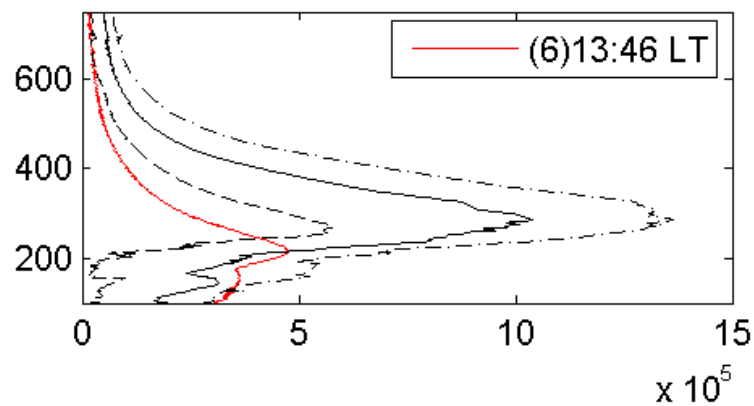
GPS



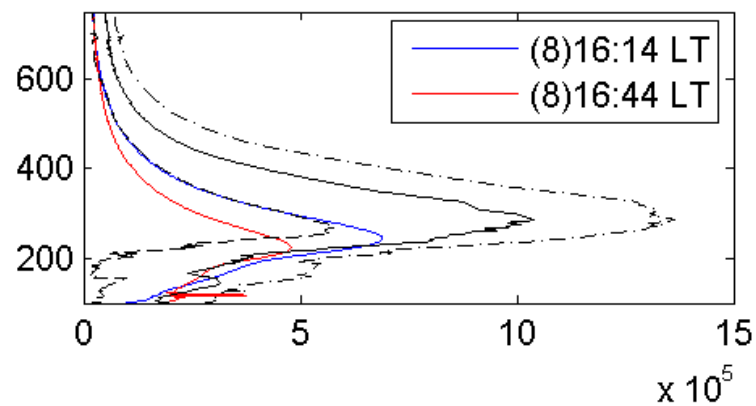




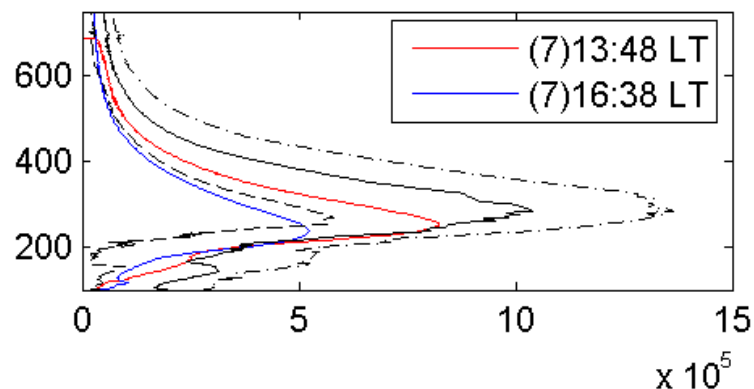
08.05/06 13:00-17:00LT



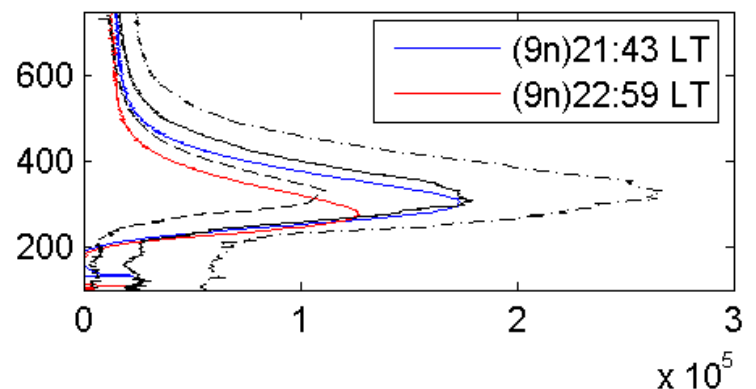
08.05/08 13:00-17:00LT



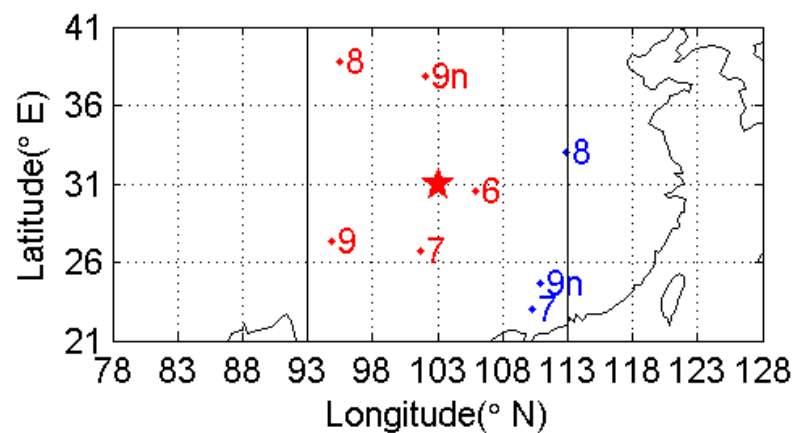
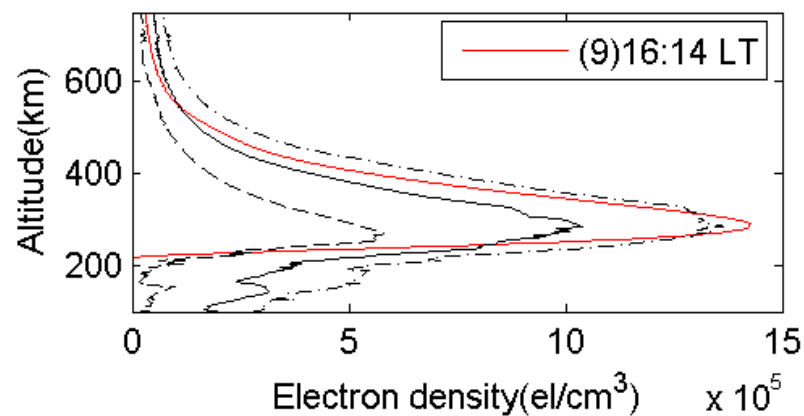
08.05/07 13:00-17:00LT



08.05/09 21:00-01:00LT



08.05/09 13:00-17:00LT



# Conclusion

- The GPS TEC results show that the ionospheric electron density tends to decrease day 6-2 before the M8.0 Wenchuan and also  $M \geq 6.0$  earthquakes in China.
- The spatial analyses show that the anomalies specifically appear over the epicenter, which strongly suggests that seismo-ionospheric precursors of the Wenchuan being observed.
- The FORMOSAT-3/COSMIC reveals that the F2-peak electron density and altitude reduces and descends, respectively, when the GPS TEC significantly decreases on day 6-2 before the Wenchuan earthquake.
- In contrast, the F2-peak electron density and altitude respectively enhances and ascends, when the GPS TEC anomalously increases over the epicenter and its conjugate point on day 3 before the Wenchuan earthquake.



# Thank you!!!

太空及遙測研究中心

太空所 ISS

